Technical Report 687

AD-A160 417

Physical Fitness as a Moderator of Cognitive Work Capacity and Fatigue Onset Under Sustained Combat-Like Operations

Robert J. Pleban and Debra A. Thomas

Army Research Institute

Henry L. Thompson

U. S. Army Command and General Staff College

Fort Leavenworth, Kansas

ARI Field Unit at Fort Benning, Georgia

Training Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

June 1985

85 10 17

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

Technical review by

Ralph R. Canter
Lloyd M. Crumley

A1

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POT, 5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
ARI Technical Report 687

2. GOVT ACCESSION NO.
AD-A160417

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
PHYSICAL FITNESS AS A MODERATOR OF COGNITIVE WORK CAPACITY AND FATIGUE ONSET UNDER SUSTAINED COMBAT-LIKE OPERATIONS

5. TYPE OF REPORT & PERIOD COVERED
August 1982-March 1983

6. PERFORMING ORG. REPORT NUMBER
--

7. AUTHOR(s)
Robert J. Pleban, Debra A. Thomas (ARI);
Henry L. Thompson (USACGSC)

8. CONTRACT OR GRANT NUMBER(s)
--

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Army Research Institute for the Behavioral and Social Sciences, Fort Benning Field Unit
P.O. Box 2086, Fort Benning, GA 31905

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
2Q162717A790
~~2348~~ 001

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, VA 22333-5600

12. REPORT DATE
June 1985

13. NUMBER OF PAGES
20

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
--

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
--

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

--

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Sustained operations
Physical fitness
Cognitive performance;
Fatigue level;
Sleep deficit,
Stress
Recovery rate,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A study was devised to investigate the role of physical fitness in moderating both cognitive work capacity and fatigue onset under sustained combat operations. Sixteen male ROTC cadets were followed through a two-and-a-half-day Pre Ranger Evaluation exercise. Prior to the actual start of the exercise the cadets' overall level of physical fitness was assessed by using five fitness indices (Harvard Step Test, chinups, pushups, situps, and two-mile run). Cognitive performance and subjective measures of fatigue state were assessed at regular intervals before, during, and one day after the (Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI Technical Report 687

20. (Continued)

exercise. The results suggest that fitness may attenuate decrements in cognitive work capacity for certain tasks requiring prolonged mental effort, particularly as the cumulative effects of sleep loss and other stressors begin to mount. Similarly, the results of this study suggest that as overall stress levels increase, fitness may have a beneficial effect in moderating fatigue rate. Fitness did not significantly enhance the recovery process with respect to cognitive work capacity, and actually appeared to hinder recovery from fatigue. Suggestions for future research are made.

Technical Report 687

Physical Fitness as a Moderator of Cognitive Work Capacity and Fatigue Onset Under Sustained Combat-Like Operations

Robert J. Pleban and Debra A. Thomas
Army Research Institute

Henry L. Thompson
U. S. Army Command and General Staff College
Fort Leavenworth, Kansas

ARI Field Unit at Fort Benning, Georgia
Seward Smith, Chief

Training Research Laboratory
Harold F. O'Neil, Jr., Director

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

June 1985

Army Project Number
2Q162717A790

Sustained Operations

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The nature of future combat is expected to entail around the clock operations without let up, for extended periods. Under such conditions, soldier resources will be depleted rapidly. Indeed, recent research has indicated that the capacity to sustain intellectual and cognitive effort begins to deteriorate within twenty-four hours of total or partial sleep deprivation, with noticeable degradation occurring in many instances following forty-eight hours of sleep loss/deficit.

The ability of the individual to successfully endure the demands imposed by high intensity continuous operations depends to a large extent on the development of effective tactics and strategies for prolonging efficient performance, particularly on tasks which have a large cognitive or vigilance component. Recent reports suggest that physical fitness may play an important role in combating the adverse effects of sustained operations on cognitive build up of fatigue.

This report presents in detail some preliminary findings on the moderating effects of physical fitness on cognitive work capacity and fatigue onset under sustained combat-like operations. It is part of the Army Research Institute exploratory development program in human performance effectiveness, and was carried out by ARI staff at Fort Benning in support of the U.S. Army Infantry Center and School.

EDGAR M. JOHNSON
Technical Director

PHYSICAL FITNESS AS A MODERATOR OF COGNITIVE WORK CAPACITY AND FATIGUE ONSET UNDER SUSTAINED COMBAT-LIKE OPERATIONS

EXECUTIVE SUMMARY

Requirements:

The nature of future combat is expected to entail around the clock operations without let up for extended periods. Recent studies indicate that under such conditions, the capacity to sustain intellectual and cognitive effort begins to deteriorate rapidly, with noticeable degradation occurring in many instances following forty-eight hours of total or partial sleep loss.

A number of factors may affect the actual rate of performance degradation. One particularly important factor may be the individual's level of physical fitness. The purpose of the present study was to examine in detail the moderating effects of physical fitness on cognitive work capacity and fatigue onset under sustained combat-like operations.

Procedure:

Sixteen male ROTC cadets were followed through a $2\frac{1}{2}$-day, Pre-Ranger Evaluation (PRE) exercise. Prior to the start of the exercise the cadets' overall level of physical fitness was assessed by using five fitness indices (Harvard Step Test, chinups, pushups, situps, and two-mile run). Cognitive performance (logical reasoning, map-plotting, and encoding-decoding) and subjective measures of fatigue state were assessed at regular intervals before, during, and one day after the exercise.

Results:

The results suggest that fitness may attenuate decrements in cognitive work capacity for certain tasks requiring prolonged mental effort, particularly as the cumulative effects of sleep loss and other stressors begin to mount. Similarly, the results suggest that as overall stress levels increase, fitness may have a beneficial effect in moderating fatigue rate. Fitness did not significantly enhance the recovery process with respect to cognitive work capacity, and actually appeared to hinder recovery from fatigue.

Utilization of findings:

The present data provide some important pieces of information regarding the relationships between physical fitness and cognitive work capacity and between fitness and fatigue onset. Specifically, the data indicate that the characteristics of the task (e.g., duration, difficulty), type of task (e.g., encoding-decoding, logical reasoning), duration of the recovery period, and length of the sustained operation may have a direct effect on the magnitude and possibly the direction of the correlations among fitness, cognitive work capacity, and fatigue onset. By systematically addressing these points in future research, a clearer picture should emerge of the effectiveness of physical fitness as a resource counter - degradation strategy for sustained operations.

PHYSICAL FITNESS AS A MODERATOR OF COGNITIVE WORK CAPACITY AND FATIGUE ONSET UNDER SUSTAINED COMBAT-LIKE OPERATIONS

CONTENTS

	page
INTRODUCTION	1
METHOD	2
Subjects	2
Materials	2
Procedure	3
RESULTS	5
The Fitness Construct	5
Method of Analysis	5
Performance Decrement and Physical Fitness	5
Fatigue Level and Physical Fitness	7
DISCUSSION	7
Cognitive Work Capacity and Physical Fitness	7
Fatigue Level and Physical Fitness	9
REFERENCES	

LIST OF TABLES

Table 1.	Partial correlations between fitness and cognitive performance across days controlling for performance differences on Day 4	6
Table 2.	Partial correlations between fitness and fatigue level across days controlling for differences in fatigue level on Day 4	8

PHYSICAL FITNESS AS A MODERATOR OF COGNITIVE WORK CAPACITY AND FATIGUE ONSET UNDER SUSTAINED COMBAT-LIKE OPERATIONS

INTRODUCTION

Recent studies (e.g., Angus & Heslegrave, 1983; Haslam, 1978; Haslam, Allnutt, Worsley, Dunn, Abraham, Few, Labuc, & Lawrence, 1977; Opstad, Ekanger, Nummestad, & Raabe, 1978) concerned with the effects of sustained military operations on performance indicate that the capacity to sustain intellectual and cognitive effort begins to deteriorate after one night of total or partial sleep deprivation, with noticeable degradation occurring in many instances following 48 hours of sleep loss/deficit. The ability of the individual to successfully endure the demands imposed by high intensity continuous operations depend to a large extent on the development of effective tactics and strategies for prolonging efficient performance, particularly on tasks which have a large cognitive or vigilance component.

Three of the four studies noted above (Haslam, 1978; Haslam et al., 1977; Opstad, Ekanger, Nummestad, & Raabe, 1978) showed that introducing small amounts of sleep ($1\frac{1}{2}$-4 hours) per 24 hours was quite effective, relative to no sleep, in either reviving performance or reducing the rate of performance decline on cognitive tasks.

However, as Kopstein, Siegal, Ozkaptan, Dyer, Conn, Slifer and Caviness (1982) note, the ultimate success of such tactics depends on how well prepared the individual/unit is to engage in sustained operations. Kopstein et al. (1982) suggest a number of long term pre-combat strategies for countering the negative effects of sustained operations on performance, such as cross-training, intense physical conditioning, practice while fatigued, etc.

A recent report by Hegge (1981) suggests that physical fitness may play a particularly valuable role in slowing the rate of performance decline during sustained combat operations. In general (Hegge, 1981), the greater the aerobic and anaerobic capacity of the individual, the lower the relative rate of resource utilization at work and the higher the relative rate of resource recovery with rest. While these relationships have been thought to hold mainly for tasks involving muscular effort there is some reason to believe that they also influence cognitive work capacity as well.

For example, Hammerton and Tickner (1968) exposed subjects classified as either fit or ultra-fit to 400 seconds of intense physical exercise. After completing the exercise, subjects' performance on a skilled visual motor task of either moderate or great difficulty was assessed. Hammerton and Tickner found that fit subjects showed no exercise-associated decrement in performance on the moderately difficult task but a marked decrement on the extremely difficult task. In contrast, ultra-fit subjects showed no decrement on the more difficult task.

Objective

The objective of the study reported here was to examine in more detail the potential moderating effects of physical fitness on cognitive work capacity and fatigue onset under sustained combat-like operations.

METHOD

Subjects

Sixteen male ROTC cadets, approximately 21 years of age from the University of Georgia and Armstrong State College participated in the study. Of these 16 cadets, 12 had applied for Ranger School in lieu of ROTC Advanced Camp for the coming summer. All cadets received approval to take part in the Pre-Ranger Evaluation exercise described in the Procedure section. During the course of the exercise one cadet was injured and could not continue and three did not complete the last day of testing because of scheduling conflicts. Consequently, most of the data analyses were based on 12 subjects.

Materials

Cognitive performance was assessed using three paper and pencil tests:

1) logical reasoning (Baddeley, 1968);
2) map-plotting (Haslam et al., 1977); and,
3) encoding-decoding (Dudley, Huband, Hartley, & Brown, 1972)

The Logical Reasoning Test, developed by Baddeley (1968), is an exercise in transformational grammar. The modified version of this test (used by Haslam et al.,1977) consists of sixteen short sentences of the following type: e.g., A does not come before B. Each sentence is followed by the letters AB or BA, and the individual is required to indicate by a check whether each of the statement is true or false. A time limit of 1 minute was used.

The Map-plotting Test is similar to the one used by Haslam et al. (1977). It consists of a blank grid of 204 5/8 in. (approximately) squares with two-digit coordinates along the two (north and east) axes. Eighteen six-figure coordinates were to be plotted on the grid. These were listed on a separate sheet of paper. A 3 minute time limit was imposed.

The Encoding-Decoding Test is a modified version of the one used by Haslam et al. (1977). It consists of fifteen six-figure grid coordinates and fifteen bigrammes (e.g., BCFK) which have to be encoded and decoded respectively using a code strip which is printed across the top of the page. The time allotted for this test was 6 minutes.

Since cognitive functioning was to be assessed on seven separate occasions (once a day), seven versions of each of the three cognitive tests were constructed to avoid possible learning of the materials.

Subjective measures of fatigue were assessed using three paper and pencil instruments. Fatigue was assessed using the Tiredness Scale (Haslam, 1978), the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973) and the Mood Questionnaire - Fatigue subscale (Ryman, Biersner, & LaRocco, 1974).

The Tiredness Scale is a 25-point scale with endpoints ranging from very fresh to very tired. The individual checks the point on the scale that best indicates his present level of tiredness. The Stanford Sleepiness Scale is a seven statement inventory describing increasing stages of tiredness e.g., feeling active and vital; alert-wide awake/almost in a dream; will be asleep soon; lost struggle to remain awake. The individual checks the statement that most closely corresponds to his present level of sleepiness. The Fatigue subscale of the Mood Questionnaire consists of a five adjective list (weary, lazy, drowsy, sluggish, and inactive). Each adjective is rated on a scale from 1 (not at all) to 3 (mostly or generally).

The cognitive and subjective measures mentioned above (with the exception of map-plotting) were incorporated in the present study because they have been shown to be sensitive to a variety of stressors including sleep loss, physical work load, and psychological stress (Haslam et al., 1977; Haslam, 1978; Opstad, Ekanger, Nummestad & Raabe, 1978). Map-plotting was included because of its perceived relevance for the Ranger exercise.

Procedure

The study covered a seven-day period divided into three phases: Days 1-3 (control), Days 4-6 (experimental), and Day 7 (recovery). On Day 1, cadets were briefed about the general purpose of the study. Starting on Day 1 and each day thereafter, at approximately 1600 hours cadets were administered the Logical Reasoning, Map-Plotting, and Encoding-Decoding Tests, in that order. The specific versions of the three tests presented to the cadets were randomized. Prior to the start of each test in each testing period the experimenter read aloud the specific instructions for that instrument to ensure that the cadets knew exactly what they were to do. This was done for each testing period. Testing took place indoors during the control and recovery periods, and for the first day of the experimental period (Day 4). Testing for the last two days of the experimental period was performed outdoors in the training area.

The purpose of the control period was to familiarize the cadets with the tests and to provide them with enough practice so that performance would be relatively stable going into the exercise (Bittner, Jones, Carter, Shannon, Chatfield, & Kennedy, 1981).

Beginning on Day 4 at 1600, both performance and fatigue measures were collected. Fatigue was assessed at 4-hour intervals throughout the experimental period and once during the recovery period (at 1600) preceding the last series of cognitive tests. (Only fatigue ratings taken at 1600 each day were utilized in this study.) At approximately 1730 on Day 4 the cadets were given a modified physical fitness test which included five measures administered in the following order: Harvard Step Test, chinups, pushups, situps, and two-mile run.

The PRE exercise formally began at 1900 on Day 4. The purpose of the PRE exercise is to provide a comprehensive evaluation of Ranger applicants in a relatively short (2½ days) but physically and mentally demanding exercise and to give applicants some insight into the magnitude of the stress involved in Ranger operations. This exercise was regarded as ideal for the purposes of the present study since it involved some of the key characteristics of a sustained operation (i.e., psychological stress, sleep loss, sustained activity, and caloric deficit).

At 1900 (on Day 4) the cadets received their operations order. Once preparations for the mission were completed the cadets were taken by truck from the ROTC building at the University of Georgia campus heavily forested military training area. For the next two days, as part of the PRE exercise, cadets took part in patrol missions, conducted raids and ambushes, and were tested on various military skills (e.g., first aid, weapons, and land navigation ability). During this time the cadets obtained approximately two hours of scheduled sleep on Day 5 (2200-2400); they were restricted to one meal (canned Army C-ration) per day, kept physically active for most of the exercise, and psychologically stressed.

The PRE exercise ended on Day 6 at 1600. The cadets were then taken back by truck to the ROTC building on campus. After approximately 24 hours of sleep/rest the cadets were tested for the final time (Day 7). Cognitive performance and subjective measures of fatigue were obtained.

Once this final phase was completed, the cadets were interviewed by one of the experimenters to get their feelings on the stressfulness of the exercise and to further probe about specific aspects of the study.

RESULTS

The Fitness Construct

The five separate fitness indices (chinups, pushups, situps, two-mile run time, and pulse rate as determined from the Harvard Step Test) were combined to form a single fitness composite score. This was accomplished by first transforming the raw scores obtained for each of the five measures into Z-scores. The Z-scores were converted into percentiles based on the percentage of the total area of the normal curve each Z-score represented. The individual percentiles were then added and divided by five (number of fitness measures) to get an average fitness rating for each cadet.

Method of Analysis

Partial correlations were computed between fitness level and cognitive performance for both number attempted and number correct and between fitness level and fatigue ratings on Days 5, 6, and 7 controlling for initial differences at Day 4- the base day (See Cohen and Cohen,1975, pp. 378-387 for a complete discussion on the assessment of change through partial correlation procedures).

Performance Decrement and Physical Fitness

The results from the analyses are shown on Table 1. Positive correlations indicate less performance decrement with increasing levels of fitness, negative correlations indicate greater performance decrement with increasing fitness. It was expected that smaller performance decrements would be associated with higher levels of fitness.

As can be seen from the table, the strongest support for this hypothesis occurred at Day 6 for Encoding-Decoding: number correct, partial $r=.50$, $p=.07$, and number attempted, partial $r=.59$, $p=.04$, where the partial correlations were moderately high and statistically significant (or approached significance). Although the partial correlations were in the predicted (i.e., positive) direction for Days 5 and 7, they did not approach statistical significance. For the remaining two cognitive tasks (logical reasoning and map-plotting), the partial correlations were either quite low or in the direction opposite from what was predicted (i.e., negative).

It may be noteworthy that the partial correlations between encoding-decoding and fitness were strongest at Day 6 which was the last day of the PRE exercise and presumably represented that point where the cumulative effects of stress would be greatest. Of further interest is the fact that the predicted pattern of correlations was shown only for the Encoding-Decoding Test which required the longest sustained effort (six-minutes) of the three cognitive tasks.

Table 1

Partial Correlations Between Fitness and Cognitive Performance Across Days Controlling For Performance Differences on Day 4

Cognitive Task	Days					
	5	p	6	p	7	p
Logical Reasoning						
No. Correct	.04	.45	-.20	.27[a]	.08	.40
No. Attempted	.03	.46	-.12	.36[a]	.32	.16
Map-plotting						
No. Correct	-.76	.01[a]	-.40	.14[a]	-.84	.002[a]
No. Attempted	-.46	.10[a]	-.23	.27[a]	-.16	.34[a]
Encoding-Decoding						
No. Correct	.33	.18	.50	.07	.26	.23
No. Attempted	.23	.26	.59	.04	.26	.23

Note. N=12 for Logical Reasoning; N=10 for Map-Plotting; N=11 for Encoding-Decoding. All tests are one-tailed.

[a]Although some of these correlations exceeded conventional levels of significance for a one-tailed test, the null hypothesis cannot be rejected. This is because the correlations noted (with the superscript [a]) were not in the predicted direction. By definition, one-tailed tests of significance preclude rejecting the null hypothesis in the direction opposite to that predicted since these tests have no power to detect such effects (Cohen, 1977).

Fatigue Level and Physical Fitness

The relationship between fatigue level and physical fitness over time is portrayed on Table 2. Positive correlations indicate increasing amounts of fatigue with increasing levels of fitness while negative correlations are indicative of less fatigue buildup over increasing levels of fitness. It was expected that fitness would attenuate the projected rise in fatigue over time and facilitate the recovery process.

As can be seen from the table, negative partial correlations between fitness and fatigue level were obtained for Day 6 only. The partial correlation between fitness and the Fatigue subscale was statistically significant, $p=.04$. Although the partial correlations between fitness and fatigue on the remaining two scales were in the predicted direction (i.e., negative) for Day 6 they did not approach conventional levels of significance.

Again, it may be noteworthy that the only supportive evidence linking fitness to lower fatigue levels was obtained at Day 6 (second day in the field) where the cumulative effects of fatigue would be expected to be greatest.

DISCUSSION

Earlier reports (Kopstein et al., 1982; Hegge, 1981; Hammerton & Tickner, 1968) had suggested that physical fitness might play an important role in combating the adverse effects of sustained combat operations on cognitive work capacity and fatigue onset by slowing the rate of performance decline and the accompanying buildup of fatigue. The evidence from this study, while not conclusive, indicates that the relationships among physical fitness, cognitive work capacity, and fatigue level may be more complex than originally hypothesized.

Cognitive Work Capacity and Physical Fitness

With respect to cognitive work capacity, the pattern of correlations obtained on the encoding-decoding task provided the strongest and most consistent support for the notion that fitness would be an effective moderator of performance decrement over time. The data seem to indicate that fitness may begin to assert its influence when the cognitive task or activity becomes more sustained in nature (e.g., 6 minutes or longer) and as the cumulative effects of sleep loss and other stressors begin to mount.

Task difficulty may have also contributed to the pattern of results that were obtained. Anecdotal reports indicated that the encoding-decoding task was the most difficult of the three cognitive tasks, as well as the longest. The importance of task difficulty as a moderating variable received some empirical support from the earlier findings of Hammerton and Tickner (1968) which showed less performance decrement with increasing levels of fitness but only for the more difficult cognitive task.

Table 2

Partial Correlations Between Fitness and Fatigue
Level Across Days Controlling for Differences in Fatigue Level on Day 4

Fatigue Measure	Days					
	5	p	6	p	7	p
Fatigue subscale	.40	.12[a]	-.57	.04	.26	.23[a]
Tiredness Scale	.78	.002[a]	-.13	.35	.54	.04[a]
Sleepiness Scale	.73	.005[a]	-.32	.16	.39	.11[a]

Note. N=11 for Fatigue subscale; N=12 for Tiredness and Sleepiness Scales. All tests are one-tailed.

[a]See comments at the bottom of Table 1.

The results from the map-plotting task are more difficult to explain. Four of the six partial correlations ranged from -.40 to -.84, suggesting a fairly strong (though not statistically significant) inverse relationship between fitness level and performance decrement. It may be that map-plotting is one task that is not affected (positively) by fitness in sustained combat-like situations. It is also possible that the pattern of results were due in part to certain subject characteristic(s) that were present in the small sample (N=10).

Fitness did not appear to play a strong role in the recovery process (Day 7) with respect to cognitive functioning. Four of the six partial correlations between performance (decrement) and fitness level at Day 7 were in the predicted direction but not statistically significant. This could be attributed to at least two things. First, with such a relatively small sample statistical power was low (Cohen, 1977). Second, the 24 hour sleep/rest recovery period may have allowed the more unfit cadets the necessary time needed for virtually complete recovery, thus attenuating the relationship between fitness and performance decrement at recovery.

Fatigue Level and Physical Fitness

Because of the extreme physical nature of the PRE exercise it was predicted that fitness would slow down the expected build-up of fatigue over time and facilitate the recovery process. This hypothesis was only partially corroborated. The negative partial correlations between fitness and each of the three fatigue measures at Day 6 suggested that as overall stress levels increase, fitness may have a beneficial effect in moderating fatigue rate. Surprisingly, however, the results showed that fitness did not facilitate the reduction of fatigue over the 24 hour sleep/rest recovery period. In fact, the partial correlations at Day 7 (and Day 5) were all positive (i.e., the more fit cadets reported the greatest level of fatigue).

The shift in the direction of the correlations from positive on Day 5 to negative on Day 6 and back to positive on Day 7 is difficult to explain, particularly given the apparent magnitude of the shifts that were obtained (see Table 2). Self-presentation concerns (e.g., Rosenberg, 1969) could explain to some degree the positive correlations on Days 5 and 7 but not the reversals from Days 5 to 6 and from Days 6 to 7.

In summary, the present data provide some important pieces of information regarding the relationships between physical fitness and cognitive work capacity and between fitness and fatigue onset. Specifically, the data indicate that the characteristics of the task (e.g., duration, difficulty), type of task (e.g., encoding-decoding, logical reasoning), duration of the recovery period, and length of the sustained operation may have a direct effect on the magnitude and possibly the direction of the correlations among fitness, cognitive work capacity, and fatigue onset. By systematically addressing these points in future research, a clearer picture should emerge of the effectiveness of physical fitness as a resource counter-degradation strategy for sustained combat operations.

REFERENCES

Angus, R.G., & Heslegrave, R.J. (1983). The effects of sleep loss and sustained mental work: Implications for command and control performance. Proceedings of the 24th Defense Research Group Seminar (Vol.1). Defense and Civil Institute of Environmental Medicine, Downsview, Ontario.

Baddeley, A.D. (1968). A 3-minute reasoning test based on grammatical transformations. Psychonomic Science, 10(10), 341-342.

Bittner, A.C., Jones, M.B., Carter, R.C., Shannon, R.H., Chatfield, D.C., & Kennedy, R.S. (1981). Statistical issues in performance testing: Collected papers (Report No. NBDL-^1 RO10). New Orleans, LA: Naval Biodynamics Laboratory.

Cohen, J. (1977). Statistical power analysis for the behavioral sciences. New York: Academic Press.

Cohen, J., & Cohen, P. (1975). Applied multiple regression/correlation analysis for the behavioral sciences. New Jersey: Lawrence Erlbaum Associates.

Dudley, R., Huband, P., Hartley, L., & Brown, K. (1972). The effects of partial sleep deprivation on some cognitive aspects of the tank commander's tasks (Report APRE No.16). Farnborough, Hants, United Kingdom: Army Personnel Research Establishment.

Hammerton, M., & Tickner. (1968). Physical fitness and skilled work after exercise. Ergonomics, 11(1),41-45.

Haslam, D.R. (1978). The eff 't of continuous operations upon the military performance of the infai..ryman (Exercise "Early Call" II) (Report APRE No.4/78). Farnborough, Hants, United Kingdom: Army Personnel Research Establis..ment.

Haslam, D.R., Allnutt, M.F., Worsley, D.E., Dunn, D., Abraham, P., Few,J., Labuc, S., & Lawrence, D.J. (1977). The effect of continuous operations upon the military performance of the infantryman (Exercise "Early Call") (Report APRE No.2/77). Farnborough, Hants, United Kingdom: Army Personnel Research Establishment.

Hegge, F.W. (1981). Control of human resources. In NATO Defense Research Group (Eds.), Study on human biomedical aspects of the sustained operation. Washington, D.C.: Walter Reed Army Institute of Research.

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R., & Dement, W. (1973). Quantification of sleepiness: a new approach. Psychophysiology, 10, 431-436.

Kopstein, F., Siegel, A., Ozkaptan, H., Dyer, F., Conn, J., Slifer, W., & Caviness, J. (1982). Soldier performance in continuous operations (Contract No. MDA903-81-C-0286). Wayne, PA: Applied Psychological Services, Inc.

Opstad, P.K., Ekanger, R., Nummestad, M., & Raabe, N. (1978). Performance, mood, and clinical symptoms in men exposed to prolonged, severe physical work and sleep deprivation. Aviation Space and Environmental Medicine, 49, 1065-1073.

Rosenberg, M.J. (1969). The conditions and consequences of evaluation apprehension. In R. Rosenthal & R.W. Rosnow (Eds.), Artifacts in Behavioral Research. New York: Academic Press.

Ryman, D.H., Biersner, R.J., & LaRocco, J.M. (1974). Reliabilities and validities of the mood questionnaire. Psychological Reports, 35, 479-484.